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THOUGHTS ON THE DISCOVERY OF LE VERRIER'S PLANET.—By Professor Olmsted.

(*From the New Englander, for Jan.*, 1847.)

At a sitting of the French Academy in June last, a paper was presented written by M. Le Verrier, a young astronomer of Paris, the object of which was to prove that there exists, in the solar system, a planet hitherto unknown, situated at double the distance of Uranus from the sun, which on the first of January, 1847, would be at or near a point in the ecliptic whose longitude is 325 degrees. This extraordinary hypothesis has recently been verified by the actual observation, with the telescope, of the body in question. It was first seen by Dr. Gallé a distinguished astronomer of Berlin, on the 23d of September, and it has since been seen at London, and more recently at various observatories in our own country.

Although in apparent brightness this stranger is equal only to a star of the eighth magnitude, and consequently must remain forever invisible to the naked eye, yet the telescope invests it with all the characters of a planet, readily distinguishing it from the fixed stars by its perceptible disk, and by its motion around the sun, which, though comparatively slow, is still vastly greater than belongs to any of the stars. It requires more than two hundred years to complete its circuit; and although its exact magnitude is not yet determined, yet enough is known to assure us that it is one of the largest of the planets, and more than a hundred times as large as the earth.

This discovery, by theory alone, of a body hidden so deep in the abyss of space, and until now invisible from the creation of the world, determining not only its existence but its exact place among the stars, proclaims most audibly the perfection at which physical astronomy has arrived; and it invests truth itself with a solemn grandeur, when we think how far into the recesses of nature it will conduct the mind, that diligently follows its leadings, even in the secret retirement of the closet.

The method of investigation, although laborious and intricate, is not difficult to be understood, but may be described in very simple terms. The planet Uranus (Herschel) has been long known to be subject to certain irregularities in its revolution around the sun, not accounted for by all the known causes of perturbation. The tables constructed with the greatest care for any particular epoch, from observations on the planet, guided and corrected by the theory of universal gravitation, do not accurately give its place at periods of a few years either before or after that time. In some cases the deviation from the true place, as determined by observation, has been two minutes of a degree—a quantity indeed which seems small, but which is still far greater than occurs in the case of the other planets, Jupiter and Saturn for example, and far too great to satisfy the extreme accuracy required by modern astronomy. From 1781, when Herschel discovered this planet, to 1821, observations had been accumulated on its motions for forty years, a period abundantly sufficient to afford the necessary data for determining the elliptic elements of its orbit. Indeed, there were older observations than these, scattered along a whole century; for before this body was determined to be a planet, it had been recognized and its places assigned as a star of the sixth magnitude. In the year 1821, Bouvard, a French mathematician of emi-

nence, compiled tables of this planet, availing himself of the most recent, and what he deemed the most perfect observations, and allowing for the perturbations occasioned by the attractions of the other planets, chiefly those of Saturn and Jupiter, which on account of their great masses, as well as their proximity to Uranus, would of course more or less disturb his motion. Bouvard himself, however, was struck with the fact that his tables were incompetent to represent the actual places of the planet, as it had been seen by the older astronomers, and he even suggested the possibility of an unknown planet, whose hidden action upon Uranus occasioned the disagreement in question.

For the benefit of such of our readers as have not given their attention to subjects of this kind, it may be premised, that, in accordance with the law of universal gravitation, every body in the solar system is attracted by and attracts every other; that such large bodies as Saturn and Jupiter exert a powerful influence in disturbing other members of the system, their effect being sensibly felt upon the earth, although, when nearest, the former is distant from us about eight hundred and the latter about four hundred millions of miles; that this disturbing force exercised by one body of the system over the others, is proportioned to its quantity of matter, or mass, and is therefore so much greater in the sun than in one of the planets, only because the sun contains so much more matter than the planet; that, in the same body, the power of attraction diminishes rapidly as the distance is increased, being four times less when the distance is doubled, and nine times less when the distance is trebled; or, as astronomers express it, the attraction diminishes in proportion as the square of the distance is increased. In order, therefore, to form tables which shall truly represent the motions of a planet revolving around the sun in an elliptical orbit, it is necessary not only to estimate the different velocities which the body would have on account of its different distances from the sun, arising from the eccentricity of its orbit, but to allow also for the united effects of all the disturbing influences (perturbations) which result from the actions of the other bodies of the system, some of which tend to accelerate it, others to retard it, and others still to turn it out of its path. Thus the exact place of a ship, even when carried forward by a uniform breeze, can not be determined from the reckoning, only after due allowance is made for all the currents that have either conspired with or opposed its progress. Before such allowances can be made and applied, the exact *weight* of each of the bodies in the system must be known; and it is one of the sublime results at which modern astronomy has arrived, that the planets have in fact been weighed as in a balance, and their respective quantities of matter ascertained with as much precision, as that of an ordinary article of merchandise.

Now the only planets in the solar system heretofore known to disturb the motions of Uranus, are Saturn and Jupiter, the other planets being so far off and so small, that their attraction is insensible. In constructing tables, therefore, to represent the motions of Uranus, or by means of which its exact place in its orbit can at any time be calculated, it was only deemed necessary to allow for the disturbing influences of these two great planets. But after making the allowances required, still, after a few years, Uranus was found by observation to deviate very materially from the calculated place. *Some* other cause, therefore, must disturb its motions beside the attractions of Jupiter and Saturn. Several hypotheses have

been at different times proposed to account for the disagreement in question.

First, it has been urged that at so remote a distance from the sun as eighteen hundred millions of miles, (the distance of Uranus,) the law of gravitation itself loses somewhat of its constancy or uniformity; consequently, tables founded on this law, as those of Uranus are, would not give results exactly conformable to observation. This hypothesis is not only unsupported by any evidence, but is at variance with all known facts in astronomy. Halley's comet, for example, during its late revolution, departed to a distance from the sun equal to twice that of Uranus, (about 3,600,000,000 of miles) yet on its return in 1835, after an absence of more than seventy-five years, it was true to the time appointed, having come to its perihelion within a day of the time assign- to it by calculations founded on the law of universal gravitation. Moreover, we have independent proof of the unerring uniformity of this law, when extended to distances far greater than that of Uranus from the sun, or than that of Halley's comet in its aphelion, since it is found to prevail even among the *stars*, regulating the revolution of sun around sun, as is now proved concerning the binary stars, those double stars of which the two members revolve about a common centre of gravity, which they do in exact obedience to the law of universal gravitation.

Secondly, the *resistance of a supposed ether*, or subtle elastic medium, diffused through space, has been assigned as the cause of the phenomenon in question. But, were this the cause, we might expect to see it manifested in the motions of the other planets, and the more as their motions are more rapid than those of Uranus. The existence of such a medium has indeed been inferred, in consequence of certain effects manifested in the movements of Encke's comet; but it may be easily conceived, that an exceedingly light body would indicate such a resistance, while a dense body like the planets would not. A particle of down may experience resistance, when moving swiftly through a medium, where a musket ball would not be sensibly affected.

Thirdly, the hidden influence in question has been ascribed to *a great satellite* of Uranus, hitherto undiscovered. But the perturbations occasioned by such a satellite would be of short period, completing a cycle during the revolution of the satellite about its primary, which would occupy but a short time, whereas the changes in the perturbations occasioned by the cause under consideration are exceedingly slow. Moreover, in order to produce effects on Uranus so great as those to be accounted for, a very large satellite, would be required, of such a magnitude, indeed, that it would not fail to be seen with the telescope.

Fourthly, the disturbing influence of a *comet*, has also been proposed to account for the irregularities of Uranus. But comets have never been known to exert any appreciable influence upon the motions of the planets. The comet of 1770 passed among the satellites of Jupiter, without sensibly disturbing their movements,—a proof that the quantity of matter in these bodies is inconceivably small. Nor, from the eccentricity of the orbits of comets, could we suppose a comet to linger in the immediate vicinity of Uranus so long, as the perturbations which it is assumed to account for are known to have existed.

Finally, the suspicion of the existence of a planet, lying beyond the orbit of Uranus, did not originate with Le Verrier, but had been entertained by several eminent astronomers, for twenty-five years before the subject engaged his attention.

But merely to *conjecture* the existence of such a body, or even to assert its existence without proof, implies very little; but to establish its existence by satisfactory evidence, and still more, to tell *where* it lies among the myriads of stars, to weigh it, to assign its distance from the sun, and the period of its revolution—these are the points of difficulty, and it is the successful solution of the problem under all these various aspects, that constitutes the glory of this youthful astronomer.

Le Verrier did not undertake the formidable task of determining these points, until he had fully proved, that the disagreement between theory and observation in the motions of Uranus, was no fault of the tables themselves; that they were true at least as far as they went. For this purpose he submitted to a new and laborious discussion the observations, both old and new, which had ever been made upon this body, from the time when its place was first noted, on the supposition that it was a fixed star, down to the present time. He re-calculated the formulæ which afforded the basis of the tables of Bouvard, and scrutinized every possible source of error in these tables. Some errors were indeed detected; but after making full allowance for these, the actual place of the planet, as determined by observation, was still widely at variance with that resulting from calculation. For example, in 1838, after calculating the maximum error which *could* exist in the tables,—an amount probably much greater than actually *does* exist,—he showed that it could not exceed 30 seconds of space, whereas the disagreement between the calculated and observed places of the planet, was 125 seconds; and, in 1831, this difference amounted to 188 seconds, of which 140 could not be explained, without admitting some other disturbing influence than that arising from the sun, Jupiter and Saturn.

Assuming, then, the existence of an undiscovered planet, the first inquiry was, *where* is it situated—at what distance from the sun—and in what point of the starry heavens?

First, it could not be below Saturn, that is, between Saturn and the sun, because then it would disturb Saturn more than it did Uranus, whereas the motions of Saturn are fully accounted for without implying any other than the attractions of known bodies. Secondly, it could not be between Saturn and Uranus; for if so, it must be very near Uranus, otherwise it would at the same time disturb the motions of Saturn. But being very near to Uranus, it must be very small, otherwise it would disturb Uranus more than it does. But a small planet, nearly at the same distance from the sun as Uranus, would be very unequal in its action on the latter planet, its disturbing force being great when in conjunction with it, but very small, or quite insensible when at a great angular distance from it. No such changes in the actual perturbations occasioned by the body occur.* Hence, thirdly, *the body must be beyond Uranus.* Is its orbit near that of the latter planet, or remote from it? It can not be very near, for then the same inequality of action would be observed, as though it were on the other side of Uranus and near to it, which inequality does not exist. Nor can it be *very* remote, for then it must of course be very large in order to produce the perturbations it does, and being very large, its effects would be visible on Saturn as well as on Uranus, as would be the case were its distance so great that the distance between these two planets

* This reasoning does not appear to be entirely conclusive, since if the two bodies in question both revolve in orbits nearly circular, and at nearly equal distances from the sun, they might remain in the immediate vicinity of each other for many years.

is small in the comparison. Thus, were it ten times as far from the sun as Uranus is, then the distance between Saturn and Uranus would bear so small a ratio to the whole distance, that a body powerful enough to affect the latter so sensibly, would exert at least an appreciable attraction on the former. Now the other planets, as we recede from the sun, have their orbits placed at distances continually approximating to the ratio expressed by 2, the distances of each planet in succession growing nearer and nearer to double that of its predecessor. Thus Saturn is nearly twice as far from the sun as Jupiter, and Uranus more nearly twice as far as Saturn. Hence it was most reasonable to expect, that the orbit of the planet sought, would be situated at twice the distance of Uranus; that is, at about three thousand six hundred millions of miles from the sun. On trial, Le Verrier found that a planet whose orbit was thus situated, would fulfil the conditions rendered necessary by the changes which the perturbations themselves undergo, and that no other distance would do it. Hence it was inferred, that *the unknown planet revolves around the sun at double the distance of Uranus.* The distance from the sun being determined, and the orbit, like those of the other planets, being supposed nearly circular, its period or time of revolution might be found by Kepler's law,—that the squares of of the periodic times are proportioned to the cubes of the distances.* By this law its period would appear to be about 237 years. This was to be regarded as only a first approximation. We shall find that the actual period is somewhat less than this.

It was easy to show that its orbit must be nearly coincident with the ecliptic, since the perturbations occasioned by it were nearly all in the direction of the ecliptic, and not at right angles to it; that is, they were perturbations of longitude and not of latitude.

To these extraordinary but apparently satisfactory results, the paper of Le Verrier presented to the French Academy at their sitting on the first of June, conducts us. Being now fully convinced himself of the existence of the planet sought, and intent on finding its true place, this able astronomer still continued his laborious researches, until he was able to deduce, mathematically, those conclusions which had before rested chiefly on analogical evidence, or at least upon general inferences derived from the doctrine of universal gravitation. Equations were formed between the irregularities of Uranus to be accounted for, and the elements of the body in question, both known and unknown. These equations involved nine unknown quantities, and their resolutions presented difficulties apparently insurmountable; but by the most ingenious artifices the several unknown quantities were successively eliminated, either directly or by repeated approximations. Moreover, in science as in morals, the pathway of truth is easy and simple, and grows continually plainer and plainer, while that of error is thorny, and, as we advance, becomes at every step more and more complicated. All who have attempted difficult solutions of mathematical or physical problems, must have been aware what unexpected facilities often suddenly appear in the resolution of complex expressions, which contain the hidden truth; they must have been most agreeably surprised, to see involved and

* Hence, the distance being double that of Uranus and the periodic time of the latter being 84 years, we have $1^3 : 2^3 :: 84^2 : 2^3 \times 84^2 = 8 \times 84^2 =$ square of the periodic time of the body sought. Therefore, the time itself $= \sqrt{8} \times 84 = 237{\cdot}468$ years.

apparently unmanageable members of equations cancelling each other, and suddenly vanishing, and difficult expressions falling off at the right and left, and constantly simplifying their work as they approach nearer and nearer to the final expression, which contains the naked truth. Hence the maxim, that *Nature is very kind to those who faithfully study her laws.*

Such encouraging facilities seem to have inspired our young astronomer, in his difficult and laborious undertaking, until he arrived at expressions for the elements of the unknown planet, which gave its exact place among the stars, its quantity of matter, the shape of its orbit, its distance from the sun, and the period of its revolution. At the sitting of the Academy on the 31st of August, these latest results were presented, stated numerically as follows:—

Longitude of the planet, Jan., 1, 1847.	326° 32′
Mass, that of the sun being 1,	$\frac{1}{9300}$
Eccentricity,	0·107
Time of revolution,	217·387 yrs.
Longitude of the perihelion,	284° 45′
Major axis of the orbit, that of the earth being 1,	36·154

He was therefore enabled to say, that the planet was then just passing its opposition, and consequently was most favorably situated for observation, and, on account of the slowness of its motions, would remain in a very favorable position for three months afterwards. In order to test the correctness of these elements, the effect of a planet, having these conditions, was investigated in relation to the motions of Uranus, in order to see how well the places of that planet, determined by the aid of these corrections for many different periods, would correspond to the places actually observed at those times. We must bear in mind, that the discrepancies between the calculated and observed places, without these corrections, was enormous, sometimes amounting to 125 seconds of an arc. The comparison was made in respect to thirty-three sets of observations, of which *twenty-six* were selected from observations made since 1781, when the planetary character of the body was first made known, and *seven* from the records of previous observers, who had marked its place supposing it to be a fixed star, from that of Flamsteed in 1690, to that of Lemonnier in 1771. The places of Uranus, determined with the new elements, agreed with the places actually observed at these later periods, generally within one or two seconds, and often within the fraction of a second; and with the earlier periods, with one exception, to within about seven seconds. These elements of the unknown body, were varied and the limits ascertained to which such changes could be carried, without involving a greater disagreement between the calculated and observed places; and these limits were found to be included within a very narrow compass. On every side the existence of an unknown planet, having these elements, forced itself on the belief of Le Verrier, and he probably felt as confident of its existence before it was seen in the heavens, as he has done since. Still it became an important inquiry at last, whether there was any hope of ever seeing the interesting stranger, or whether after so much toil, the indefatigable student must rest his belief in its existence, solely upon his faith in the immutable laws of truth, whose leadings he had followed into depths of space so profound, and must take his dubious chance for fame in the weak belief of the few, and the total incredulity of the many. In estimating the probability that the planet would be visible to the telescope, he reasoned thus. Uranus has an apparent diameter of four seconds, and since the mass, or quantity of matter, of this planet is two and a half times less than that

of the planet sought, were the density of the latter known, we could easily find its volume, and then, knowing as we do its distance, its apparent diameter would be easily determined. Now it is a known fact, that the densities of the planets decrease as we recede from the sun, and therefore the density of the body in question is probably less than that of Uranus,—a circumstance which would contribute to increase the comparative volume, and of course the apparent diameter. But even allowing the density to be as great as that of Uranus, the apparent diameter will be over three seconds, and consequently, the planet ought to be visible in good telescopes, and with a perceptible disk. If among the small stars situated in that part of the heavens where the planet is at present, a faint body be discerned having a perceptible disk, it will at once be recognized as the planet itself; but if no such appearance should distinguish it from the small stars surrounding it, then a map of these must be carefully inspected; and if any one of the luminous points included in the map shifts its place, indicating a movement more rapid than belongs to any of the fixed stars, then that luminous point will be recognized as the body sought. It happened, fortunately, that charts of that region of the heavens were in the course of publication at Berlin, containing a perfect representation of all stars to the tenth magnitude; and the very folio containing the constellation Capricornus, in which the hidden body was supposed to be, was then just issuing from the press. Le Verrier, therefore, wrote to M. Gallé of Berlin, communicating his latest results, and requesting him to reconnoitre for the stranger, directing his telescope to a point about five degrees eastward of a well known star called *Delta Capricorni.* So precise and complete were these directions, that the Prussian astronomer no sooner pointed his telescope to the region assigned, than he at once recognized the wondrous body. Its place was only 52 minutes of a degree distant from the position marked out for it by Le Verrier, and its apparent diameter was almost the same that he had assigned.

M. Gallé's letter to Le Verrier announcing his discovery, reached the latter while an article of his on the latitude of the planet, was in the course of preparation for the sitting of the Academy on the 5th of October. This confirmation of all his hopes, is added to his paper in a modest postscript, in terms less evincive of exultation than might have been anticipated. But the very phraseology of Gallé indicates that, previous to the actual discovery, he had himself but feebly embraced the idea of its existence. "The planet (says he) which you have described, *really exists!*" The congratulatory letters which now flowed in from the most celebrated astronomers of Europe, occupy a conspicuous place in the Comptes Rendus of Oct. 5th, being communicated to the Academy by M. Arago, accompanied by very interesting remarks on the history and importance of the discovery. "Other astronomers (said M. Arago) have sometimes found, accidentally, a *movable point*, in the field of their telescopes, which proved to be a planet; but M. Le Verrier descried the new body without having occasion to take a single look towards the heavens—he saw it *at the point of his pen.* He determined, by the power of the calculus alone, the place and the magnitude of a body situated far beyond the known limits of our planetary system; of a body whose distance from the sun exceeds 1200 millions of leagues, and which in our most powerful telescopes offers a disk scarcely perceptible. In fine, the discovery of Le Verrier is one of the most brilliant manifestations of

the exactness of modern astronomical systems; and it will encourage the ablest geometers to search, with new ardor, for the eternal truths which, according to an expression of Pliny, *lie hidden in the majesty of theories.*" M. Arago adds, that he had received from M. Le Verrier a most flattering commission—the right of naming the new planet, and therefore he proposes to call it *Le Verrier.* When Sir William Herschel first discovered the planet Uranus, he named it after his royal patron, *The Georgian;* but this being an unpopular appellation in France, La Lande proposed to call it *Herschel*, and this name has continued in our own country to the present time. But, as the other planets have names derived from the ancient mythology, as Mercury, Venus, Mars, Jupiter and Saturn, it seemed to the leading astronomers of the day, most accordant with sound analogy and good taste, to give it a corresponding appellation; and they, therefore, after proposing a number of mythological names, fixed upon that of Uranus, (the most ancient of the gods,) and this name has generally prevailed. But Arago, for the sake of securing the desired honor to Le Verrier, proposes to restore the same to Herschel, and that the planet Pallas also shall be named from its discoverer *Olbers.* The names *Janus*, *Neptune* and *Oceanus*, have also been proposed by others; and time only can decide which of the names will finally prevail.

For a time the contest for the honor of this achievement, seemed likely to awaken the ancient national rivalries of France and Great Britain. The English astronomers claimed that a young mathematician of Cambridge, Mr. Adams, had, without the least knowledge of what M. Le Verrier was doing, arrived at the same great result. But having failed to publish his paper until the world was made acquainted with the facts through the other medium, he has lost much of the honor which priority of discovery would have gained for him, although great admiration may ever be felt for his genius and capacity. In the history of great discoveries and of great inventions, it is a remarkable fact, that the same idea has frequently occurred to two individuals nearly at the same time. Thus it is still a question, whether Newton or Leibnitz first devised the method of Fluxions; and the greatest single discovery in Chemistry, that of oxygen gas, was made almost simultaneously by Priestly in England, Scheele in Sweden, and Lavoisier in France. The explanation is easy. The secret rests in the Eternal Mind, and is withheld from the view of man, until, in the progress of society, all things are ready; then the curtain is withdrawn, and Truth darts her heavenly rays upon the few, who are at the moment gazing towards her with the clearest vision. Would we give the due meed of praise to all who have contributed to bring about this grand triumph of the human mind, our honors must be widely distributed. In the noble array of intellects which would stand before us, Newton, who furnished the mighty key that turns the secret wards of creation, must undoubtedly occupy the highest place. But Kepler, who first traced the existence of laws in the planetary system; Flamsteed, Lemonnier and Bradley, who noted the places of the planet Uranus, at different periods, mistaking it for a fixed star; Herschel, who brought it to light and established its planetary character; Leibnitz, La Grange, and La Place, who invented and perfected that wonderful instrument of research into the arcana of nature, the fluxionary calculus: these all, and many more, are entitled to share with Le Verrier the glory of this discovery.

It is characteristic of great truths, that have been attained by long and

laborious processes, to draw after them many other great truths, which they serve to establish. If their discovery has brought into requisition the profoundest principles of science, it follows that those principles, leading as they have done to a correct result, a result which nature owns, are themselves true, and receive, in the discovery, a confirmation the more signal as that result is the more hidden from ordinary view. Seldom has this point received so beautiful an illustration as in the discovery of Le Verrier's planet. Let us glance at the several great truths which this discovery confirms and illustrates.

In the first place, it affords a triumphant proof of the truth of *the law of universal gravitation.* It was the knowledge of this law, which first suggested the existence of such an undiscovered planet, since it was only on the supposition of the universal prevalence of of this law, that the unexplained irregularities in the motions of Uranus, were referred to such a hidden body. It was also by the application of the law of universal gravitation, in its exact expression, namely, that it acts in proportion to the quantity of matter, and inversely as the square of the distance, that the invisible cords which bound the stranger to the planet Uranus were followed back through the depths of space, until they revealed in the wide expanse of heaven, the very spot where it lay concealed. The law of gravitation, therefore, answers completely to the test proposed by Lord Bacon, that before a new discovery can be considered good, nature should respond to it through all her works. *Non canimus surdis*, *respondent omnia silvæ.* It is said that Newton, when engaged in his first computation on the motions of the moon, instituted for the purpose of verifying his theory of gravitation, seeing, as he approached the end of the solution, that all was coming out in exact numerical conformity to the doctrine, was so overwhelmed with the great consequences of the discovery, that he grew nervous and was unable to complete the computation, but was obliged to hand it over to a friend to finish it. These consequences were, indeed, well fitted to overpower even the mind of Newton, since the simple truth which was beginning to shine out with perfect clearness in his mathematical expressions, unveiled nothing less than the hidden mechanism of the Universe, and would give to the astronomer the power, almost divine, of looking through all time, present, past, and future. But, probably, Newton himself did not at once comprehend in his mighty grasp all the great consequences of the truth he was approaching. The astonishing reach of the principle of universal gravitation can scarcely now, after the lapse of one hundred and fifty years, be fully comprehended, since almost daily, like a sounding line sent out into the depths of creation, it is disclosing to us new wonders respecting the worlds hidden in the abyss of space. How vast and unexpected are the results it has afforded in our knowledge of the grand machinery of nature! It accounts for all the celestial motions, whether of planets, comets, or stars; it teaches how to weigh the sun and planets as in a balance; it assigns the exact figure of the earth, and of every body in the solar system, independently of any measurement or observation; it explains not only the ordinary motions of the heavenly bodies, but all their irregularities, of which the moon alone has no less than sixty, and assigns the exact numerical value of each; it accounts for the tides, and, with the aid of a few observations, computes the height for every time and place; it teaches how, by means of the pendulum, to fix an invariable standard of

weights and measures; it suggests new fields to the eye of observation, directing attention to objects which have eluded the keenest vision, aided by the highest powers of the telescope, and corrects the last refinements of instrumental measurement; it has led to the grand result of the stability of the Universe, amid all the apparent causes of disorder and ruin; it follows the comet through all the planetary realms, almost to the region of the stars, and brings it back again on the day which itself appoints for its return; and, finally, it tells us of new planets still lurking in the solar system, points out their hiding places, assigns their exact weight and the period of their revolution, and directs the practical astronomer precisely where to point his telescope, to bring them down to earth. If any thing more could be wanting to establish the truth of the doctrine of universal gravitation, we surely have it in this last and most wonderful of all its revelations.

In the second place, the discovery under review proclaims the unerring certainty of the *method of Fluxions*, or the *Infinitesimal Calculus*. The fundamental principles of the Calculus are difficult to be expressed in an elementary form. So refined and almost spiritual are some of them, that it is only after having made some proficiency in the use of this method, that the learner feels fully assured that it rests on a foundation as immutable as pure geometry itself. But the discovery before us was attained by the calculus, applied, in its most refined and subtle forms, to the law of universal gravitation. The hidden truth was caught in its magic folds, but was so deeply involved within them, that to develop it and bring it, in its simple unity, to the light of day, required a labor and a skill which may well be compared to the task of finding a grain of gold when hidden among the sands of the sea shore, and as exceeding all that the ancients conceived of the difficulty of threading one's way through the mazes of the Cretan labyrinth. Moreover, if we resolve the Calculus itself into the elementary principles of mathematics which it employs, in one or other of its processes, we shall find that the whole of this science is inwoven in its fabric; and it follows, that a confirmation of the truth of the method of Fluxions, is, at the same time, a confirmation of the exact, eternal truth of the entire science of mathematics.

In the third place, the discovery of Le Verrier's planet, proves that *the other planets of our system are correctly weighed.* It is only on the supposition that the quantity of matter in Jupiter and Saturn is exactly determined, that it could be inferred that their united actions upon Uranus, to disturb his motions, was insufficient to account for his irregularities; nor, had there been any essential error in the estimates of the masses of those planets, could it have been determined what amount of error remained to be accounted for by the hidden body.

In the fourth place, we derive from this discovery new confidence in the *uniformity of the laws of nature.* This doctrine, now so generally taken as an axiom, is by no means self-evident, nor has it always been actually believed. The ancient schools of philosophy taught just the opposite doctrine, averring that we could never know from what takes place in our world, what laws prevail in distant worlds; that motion itself was one thing on earth, and perhaps quite another thing in the skies. Such a belief was the natural fruit of their mythology—a religion which distributed the several parts of the natural world to different divinities, Jupiter being lord of the air, Neptune of the sea, and Pluto of the realms below; while various subordinate deities controlled particular kingdoms in the great empire of nature, Eolus presiding

over the winds, and Urania over the starry sphere. In these distant and independent realms, therefore, it was natural to believe that different laws prevail as different monarchs rule; but the religion of the Bible, teaching as it does the doctrine of one God, leads us to anticipate the grand result, proclaimed by all the discoveries of astronomy, of a perfect uniformity in the laws of nature, throughout her boundless realms, in earth, in air, in ocean, and in the remotest planets and stars.

Finally, the *harmonies of truth*, and the attribute by which she remains forever one and indivisible, are strikingly illustrated in the example before us. The astronomer in his closet constructs a series of mathematical formulæ, complicated perhaps, but all rising upon the immutable basis of mathematical demonstration. These he transforms, in a thousand ways, spreading them over reams of paper. All the while the truth, for which he is seeking, lies concealed deeply hidden beneath massive piles, with which it is encumbered. These one by one, often to the surprise of the operator himself, melt away, until, at length, the truth, so long and so laboriously sought, divested of every disguise and incumbrance, shines out in its own native simplicity and beauty. But if it is true in theory, it is true also in fact; and the astronomer now sallies forth from his closet, and looks upward with his telescope, and there sees the confirmation of all his labors written on the skies. Not only do we find here new cause to admire the harmonies of truth, but its *fertility*, or the power of truth to beget truth, urges itself upon our consideration with new force, when we think how the discovery of the planet Uranus has furnished the key to the discovery of another planet nearly twice as far removed into the depths of space, which, again, in its turn, has perhaps an equal chance of guiding us on the way to still more distant worlds.

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the enumeration of what
has been done in Ashm-
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Dawes